From the Cognitive to the Biological: A Sketch of Arthur Jensen's Contributions to the Study of *g*

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One of Arthur Jensen's major contributions to the field of individual differences has been his investigations of the nature of *g*. Starting with relatively small-scale reaction time studies, Jensen and his colleagues' research on *g* rapidly evolved to include multiple measures of the speed with which individuals could process different kinds of information. The results of these studies, combined with Jensen's interest in the biological basis of *g*, led to behavioral genetic studies of intelligence and speed-of-processing, and, most recently to the study and identification of a number of biological/physiological correlates of *g*. This sketch provides a brief overview of these aspects of Jensen's lifework.

By coincidence, on the day that I started to write this piece, I received a copy of Arthur Jensen's most recent book: *The g Factor: The Science of Mental Ability* (Jensen, 1998). The jacket cover of this book describes Jensen as having had "a brilliant 40-year career that has earned him a place among the most frequently cited figures in contemporary psychology"; an assessment, I suspect, that many of us who work in the area of individual differences and mental abilities would agree with. But what is it about Jensen's career that has entitled him to the prominent position that he so deservedly occupies? I believe there are three main reasons:

1. He has been a leader who has blazed several trails that others have subsequently followed.
2. His research and his scholarship are characterized by exceptional thoroughness and scientific rigor.

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3. He has not balked at taking unpopular positions when, in his estimation, the data have supported these positions.

In this piece, I focus on one aspect of Jensen's research into the nature of human intelligence—his work on reaction times (RTs) and speed of information-processing—and illustrate how his pioneering work in this area has evolved from a few early studies with the Hick apparatus, through more extensive multivariate studies, to univariate and multivariate behavioral genetic investigations, and most recently, to studies of the biological basis of intelligence.

Jensen's first RT study (Jensen & Munro, 1979) was a small-scale investigation involving just 39 9th grade girls. These subjects were given the Raven Matrices and had their RTs tested with the Hick apparatus. The correlation between Raven scores and RTs was -.39; the multiple correlation between Raven scores, RTs, and standard deviation of RTs was .42.

From this modest beginning, Jensen embarked on a systematic program of research investigating relationships between intelligence and a number of RT-related parameters derived from the Hick apparatus. Within just eight years of the Jensen and Munro (1979) study, Jensen (1987) summarized the results of 33 IQ/RT investigations, the majority of which were carried out by himself and/or his graduate students and collaborators. Based on data collected in 26 independent samples from a total of almost 2000 subjects, the n-weighted mean correlation between RTs and IQs was -.201, rising to -.309 after correction for attenuation due to unreliability.

RTs derived from the Hick apparatus reflect what might be termed a subject's *general* speed of information-processing. Working in Jensen's lab, I (e.g., Vernon, 1983) and other at that time graduate students (e.g., Ananda, 1985; Braden, 1985; Paul, 1984), as well as numerous other researchers working quite independently of Jensen, showed that the speed with which subjects could execute a number of more *specific* cognitive processes, such as encoding information, scanning information in short-term memory, or retrieving information from long-term memory, also yielded significant correlations with IQ scores. Moreover, although the RTs that we obtained in different tasks tended to be quite highly intercorrelated, they still yielded sizeable multiple correlations when entered into multiple regression analyses with IQ as the criterion. In one such multivariate study, for example, conducted with 102 pairs of adult monozygotic (MZ) and dizygotic (DZ) twins, the multiple correlations between IQs and RTs derived from 8 different tasks were .74 among MZs and .62 among DZs (Vernon, 1989); indicating that as much as 50% of the variance in IQ scores could be accounted for by the speed with which subjects could execute a number of basic cognitive processes.

In this same paper, Vernon (1989) reported heritability coefficients for 11 different RT measures. These heritabilities ranged between .24 and .90, averaging .49, indicating that individual differences in speed of information-processing are attributable at least in part, and in some cases quite extensively, to genetic factors. Moreover, there was a moderately strong positive correlation of .604 between the RT tests' heritabilities and the degree to which these tests correlated with the g factor extracted from an IQ test. Thus, the more heritable an RT test, the higher its correlation with g; or, from the other perspective, the more g-loaded a test—even a relatively simple RT test—the more highly heritable it is. This use of the method of "vector correlations" ties in well with Jensen's own results showing strong positive correlations between the *g*-loadings of different tests and the tests' correlations with such biological variables as cerebral glucose metabolic rate, averaged evoked potential habituation amplitude and waveform complexity, and head size (Jensen, 1998). The results are also compatible with those of Baker, Vernon, and Ho (1991), who reported genetic correlations of 1.0 and .92 between RTs and Verbal and Performance IQ scores, respectively, which strongly suggest that speed-of-processing and IQ may share some common biological mechanisms.

In addition to his RT research, Jensen has been actively engaged in the search for these biological correlates of human intelligence. In a series of studies, Reed and Jensen (1989, 1991, 1992, 1993a) reported significant correlations between IQs and visual evoked potentials, brain nerve conduction velocities (but not arm nerve conduction velocities), and visual pathway nerve conduction velocity. Other studies of nerve conduction velocity (NCV) have yielded mixed results: a recent review of the 9 NCV/IQ studies conducted to-date (Vernon, Wickett, Bazana, & Stelmack, in press) reported significant correlations in 6 independent samples, nonsignificant correlations in 6 other independent samples, and a significant negative (i.e., wrong direction) correlation in one further sample. The evoked potential/IQ literature has also yielded equivocal results, although P300 latencies have fairly consistently showed significant correlations; supporting RT studies and indicating that persons of higher IQ are able to make decisions more rapidly than persons of lower IQ (Vernon et al., in press).

Jensen (1994; Jensen & Johnson, 1994; Jensen & Sinha, 1993; Reed & Jensen, 1993b) has also researched relationships between head size, brain size, and IQ. This is an area where there is no question but that significant correlations exist. Wickett (1997; Wickett, Vernon, & Lee, 1994; Vernon et al., in press) has recently reviewed every head size, brain size, and IQ study conducted to-date, and reports an average head size/IQ correlation of .19 (based on 54 independent samples and 56,793 subjects, this correlation is significant at $p < 1 \times 10^{-466}$!) and an average CT or MRI-estimated brain size/IQ correlation of .35 (based on 16 independent samples and 716 subjects). The functional significance of these significant correlations remains unclear but there can no longer be any doubt that persons of higher IQ have larger brains.

Currently, the search for other biological correlates of human intelligence continues full-force. Other labs around the world have conducted NCV studies (e.g., Barrett, Daum, & Eysenck, 1990; Rijsdijk & Boomsma, 1997), and there is a long history of research on intelligence and evoked potentials (see Vernon et al., in press, for a recent review); molecular genetic investigations have begun to attempt to identify specific genes that contribute to variability in intelligence (e.g., Plomin, et al., 1994); and exciting results have emerged from a number of independent labs studying relationships between IQ and cerebral glucose metabolic rates (e.g., Haier, et al., 1988; Parks, et al., 1988). Jensen has not been directly involved in all of these researches, nor are they all necessarily based on his own earlier RT and biological research. Nonetheless, his influence is evidenced by the fact that much of the biological work being conducted today can be traced back to his innovative attempts to account for variation in *g* in terms of simple, underlying processes, first at the cognitive and now at the physiological level.

This brief sketch has touched on only one part of Jensen's lifework, albeit a part that has contributed a great deal to our understanding of the nature of individual differences in intelligence. Through his own studies, the studies conducted by his students, and the work of others whose only connection with Jensen has been from reading his articles and reacting either positively or negatively to what he had to say, a huge body of research and knowledge has been amassed about the nature of *g*. When this is combined with his many other contributions, summarized in his introduction to this issue, Arthur Jensen must be recognized as one of the major figures in the history of the psychology of individual differences; his lifework has truly made a difference.

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